SUMMARY REPORT

A FEASIBILITY STUDY FOR A STREAMBANK STABILIZATION PROGRAM FOR THE BITTERROOT RIVER, MONTANA

SUMMARY REPORT

A FEASIBILITY STUDY
FOR A STREAMBANK STABILIZATION PROGRAM
FOR THE BITTERROOT RIVER, MONTANA

Prepared for

Water Resources Division
Montana State Department
of Natural Resources and Conservation
Helena, Montana

By

Daryl B. Simons
Principal Engineer

Ruh-Ming Li
Principal Hydraulic Engineer

Shelley Ellis
Watershed Biologist

James D. Schall
Senior Hydraulic Engineer

Simons, Li & Associates, Inc.
PO Box 1816
Fort Collins, Colorado 80522

February 18, 1981

PURPOSE OF THIS REPORT

This summary report is a condensed version of the Simons, Li & Associates, Inc. comprehensive technical report that resulted from the investigation and analysis of the Bitterroot River system. The purpose of the summary report is to present the results of the study without the detail and complexity of the technical report. For additional information beyond what is presented in this report, the reader is referred to the technical report. A limited number of copies of the technical report are available at the Montana Department of Natural Resources and Conservation, Helena, Montana.

ACKNOWLEDGEMENTS

Many people provided assistance in conducting this investigation, and without their help we could not have completed the study in such a short time. Initially, we would like to thank Mr. Chris Hunter and other staff of the Department of Natural Resources and Conservation, State of Montana, for their guidance and input throughout the study. Additionally, people in the Bitterroot area were particularly friendly and helpful during the collection of initial information and data. Specifically, we would like to offer thanks to Mr. Leonard Peterson, Mr. Dick Ormsbee and Mr. Tom Murphy of the Bitterroot Conservation District, who familiarized us with the Bitterroot area and assisted us in obtaining many informative documents. Also, Mr. Bob Hammer and Mr. L. M. Powell of the Bitterroot National Forest supplied specific information and data necessary to conduct the study. Finally, thanks go to Mr. Don Peters of the Montana Fish and Game Department, and Mr. Andy Carlson, who coordinated our float trip. The cooperation of these people and others greatly expedited the study and helped in the development of a strong data base.

I. INTRODUCTION

1.1 The Problem

The Bitterroot River is a dynamic river that has experienced substantial channel alteration during recent years. This channel alteration has included lateral migration of the main channel, development of multiple channels and extensive bank erosion and bank sloughing. The impacts of these changes have created problems for adjacent land owners, farmers, sportsmen, and others who use and enjoy the natural resources of the Bitterroot Valley, which include the river and its major tributaries.

Problems resulting from lateral migration of the channel, bank erosion and sloughing in the Bitterroot River include loss of valuable riparian land and some reduction in the quality of sport fishery due to localized siltation of spawning beds from sudden increases in sediment load. Lateral migration has also created problems with irrigation diversions and headgates. For example, when the main channel shifts, water diversion structures may no longer be able to access water, particularly during periods of low flow. Additionally, bridges have been left to span dry land as the river established a new path through the valley.

To develop a better understanding of the Bitterroot River channel instability, the Montana Department of Natural Resources and Conservation (DNRC) solicited proposals to conduct a comprehensive investigation of this problem. Simons, Li & Associates, Inc. (SLA) of Fort Collins, Colorado, was awarded the contract for this investigation in late November, 1980. This report and a more detailed technical report present the results and conclusions of that investigation.

1.2 Objectives of the Study and Solution Approach

The primary objective of this study was to investigate the causes of channel instability and to suggest methods of enhancing the stability of the Bitterroot River, particularly in the reach between Hamilton and Stevensville. Naturally-occurring channel instability is not uncommon in a dynamic river system; however, both natural and man-made events can complicate the situation. Distinguishing between changes due to the natural dynamic characteristics of this type of watershed and those due to man's activities is difficult. Defining the factors that influence channel instability and identifying their relative importance is essential to understanding the conditions existing in the Bitterroot River.

The dynamic nature of river and watershed systems requires that local problems and their solutions be considered in terms of the entire system. Natural and man-induced changes in a river can frequently begin "chain reactions" affecting long distances both upstream and downstream (Simons and Senturk, 1977). Successful river utilization and water resources development require a general knowledge of the entire watershed system and the processes affecting it. Analysis of the Bitterroot River utilized this system evaluation approach. Only as a consequence of careful analysis can a management scheme be developed that will assure an acceptable degree of stability in this system.

The type of instability existing in the Bitterroot River is the result of a combination of causes. Methods used to investigate the instability problem include: (1) inspection of the river system by viewing the area, (2) a review of the geology of the area, (3) analysis of aerial photographs, (4) a historical review of land-use practices, (5) geomorphic classification of the river,

(6) interpretation of climatic and hydrologic data, (7) analysis of sediment transport in the river system, and (8) a general application of geomorphic, engineering, and environmental principles of the system, as well as economic considerations, to formulate reasonable solutions.

II. PAST AND PRESENT CONDITIONS

2.1 Aerial Photograph Interpretation

Aerial photographs provide a historical record of changes in the river system. By comparing 1979 photographs to those taken in 1937, it is possible to trace the change in channel location to gain insight into how the channel has shifted in the past 43 years. The reach extending from the vicinity of Tucker Crossing to Stevensville Bridge has altered its course substantially in certain sections. In several locations gravel bars have shifted, old loops have been destroyed, and new flow paths created. In other portions of the river only minor changes have occurred, particularly in the west branch of the river south of Victor Crossing. However, the east branch has been distinctly altered. Braiding has increased noticeably in both the section between Victor Crossing and Bell Crossing and the section north of Bell Crossing. South of the Stevensville Bridge the river has cut off three bends, resulting in considerable straightening and steepening of the channel. Comparison of the 1937 and 1979 photographs clearly indicates the river channel is undergoing significant readjustment.

2.2 Land-Use Practices

Sediment yield from a watershed is a function of land-use practices. Large-scale changes in vegetation resulting from fire, logging practices, land conversion and urbanization can increase total sediment yield from a watershed. Small-scale changes made at the local level can also increase sediment yield. Bank protection techniques utilized by one land owner can result in increased bank erosion on neighboring land. Knowledge of the changes in land use over a long period of time is essential to understanding

present conditions in the Bitterroot watershed.

Increases in the flow and sediment supply to a river can accelerate channel instability. The effects of several different activities can accumulate and contribute to channel braiding. As man's activities in the area intensified during the past century, the river system may have been affected to some extent. Disturbances to the land surface and stream channels can accelerate erosion and increase sediment loads into the Bitterroot River. Early in the 1900's the east-side valley slopes were heavily grazed by sheep. Overgrazing increases erosion rates from slopes, as well as from creek banks. Animals tend to trample creekside areas, dislodging sediment and altering natural bank slopes and channel shapes.

Poor logging practices can also have an adverse impact on a river system. In the past, horse logging methods involved hauling logs down the center of the stream channels. This practice gouged out sediments and destroyed the natural channel configuration. Even today, some of these channels have not yet recovered (Hammer, 1980). Later, tractor logging was introduced and steep slopes were indiscriminately logged with heavy machines that tore up the ground. Poor quality roads were constructed with no consideration of disturbances to the watershed. Poorly designed dirt roads can be a significant source of sediment during heavy rains. Very often, no culverts were installed when roads crossed creeks. Present logging practices are carefully planned to minimize erosion, yet it is conceivable that the sediment produced during the past could still be moving through the system, affecting channel morphology. Additionally, huge clearcuts have been made in the past. Clearcutting can affect snowmelt timing, water yield, and sediment yield from an area. In the past, clearcutting and

terracing the area for planting purposes "undoubtedly increased peak flows generated from cut-over areas" (U.S. Environmental Protection Agency, 1975).

The Sleeping Child Burn in 1961 accelerated erosion and channel degradation. This fire burned a total of 28,000 acres of land, leaving the soil exposed and resulted in amplified runoff and sediment yield. The fire burned an estimated 7526 acres at the head of the Sleeping Child drainage. A substantial area of bare ground existed as much as 12 years after the fire and sheet erosion carried off much of the thin topsoil (Garn and Malmgren, 1973). After the fire, salvage operations attempted to harvest the logs as quickly as possible. Substandard roads were constructed too close to stream channels. Additionally, materials were apparently cast down into the channels during road maintenance.

Irrigation practices have also altered flow and sediment loads in the Bitteroot. Dam construction and maintenance has very likely affected sediment production. Reservoirs serve as sediment traps, storing sediments until flushing occurs. Sediment is discharged when a reservoir is drained to repair the dam or a dam may fail and produce sudden high flows capable of moving large amounts of sediment. In May, 1948, Fred Burr Reservoir failed, releasing a peak flow of about 23,000 cfs. This flow was forceful enough to move large boulders and significantly degrade the channel. (Normally Fred Burr Creek carries a peak flow of about 250 cfs.) Channel disturbances also occur if surplus water is dumped into the creeks when diversion ditches exceed their capacity. This abnormal flow results in sediment deposition where the flow is diverted from the creek, and subsequent flushing when water is dumped back in. Ditch blowouts can also contribute sediment to the stream system.

In 1890, a mill pond was constructed on the Bitterroot River for the purpose of storing and handling saw logs. The main channel was dammed near Hamilton from 1890 until 1938 when the dam washed out. This dam undoubtedly altered the sediment flow in the river. Sediment had settled out in the quiet water behind the dam, creating accumulations that were flushed out in 1938 when the dam failed.

The population of Ravalli County has nearly doubled in the past 20 years. Residential development involves construction activities that remove vegetation, compact soils, and consequently increase surface runoff. Road systems in housing subdivisions are potential sediment sources especially during initial construction when storms can wash erodible materials into the streams. Housing developments can also reduce the land area capable of absorbing rainfall, and consequently runoff may increase.

River channel stability can be affected by floodplain development. Bank erosion may be further aggravated by construction of homes on river banks, operation of equipment on the floodplain adjacent to the banks, location of roads that may cause unfavorable drainage conditions, saturation of banks by leach fields from septic tanks, and increased infiltration of water into the floodplain as a result of changing land-use practices. If the banks become saturated and possibly undercut by the flowing water, blocks of the bank may slump or slide into the channel.

Man-made alterations of the Bitterroot River channel itself lead to accelerated channel instability. Instances in which the channel has been bulldozed to straighten the river's course significantly affect river morphology. Additionally, the impact of bulldozing can destroy fisheries habitats and spawning beds. Haphazard riprapping causes the river to shift in an

unplanned fashion. Unless properly designed and placed, bank revetment can be more destructive than beneficial, particularly to the channel adjacent to and downstream of bank protection works. Often bank protection techniques involving use of car bodies, tires, and other debris simply washes downstream and deposits in undesirable locations. Systematic use of spur dikes or wing walls has been attempted, but without the full cooperation of land owners, such measures have been unsuccessful. Effective control of bank erosion will require a basin-wide plan. Bank erosion protection devices installed by individual land owners must satisfy the requirements of such a plan, or be prohibited, if success is to be achieved.

2.3 Irrigation and Reservoirs

Approximately 111,000 acres in the Bitterroot Valley are irrigated (Senger, 1975). Surface water provides nearly all of the irrigation water, with ground water supplying only about 3000 acres. About one-third of the irrigated land in the valley is supplied by the Bitterroot River, while the remainder is supplied by tributary flow. Appropriations exceed stream flow and all rights can be filled only during peak flows. Peak consumptive use occurs in late July and early August.

Two major reservoirs have been constructed for storage of irrigation water. Painted Rocks Lake on the west fork of the Bitterroot River was completed in 1940 and has a storage capacity of 31,700 acre-feet. However, it remains essentially unused for irrigation purposes. Some of the water has been purchased to augment low flows and consequently improve trout habitat in the Bitterroot River. Lake Como on Rock Creek was created in 1909 and has a storage capacity of 34,800 acre-feet. About 19,000 acres are irrigated from

Rock Creek, mainly on the east side of the valley. The total storage capacity of all the reservoirs currently in use is 81,000 acre-feet. This value represents only five percent of the total volume of water annually discharged at the mouth of the Bitterroot River. This small amount of storage has minimal effect on reducing peak flows and possible flood damage. Generally speaking, unless an excess of at least 20 percent of the annual runoff is stored in reservoirs, the impoundments have virtually no effect in reducing peak flows.

A complex network of irrigation ditches extends throughout the valley. Late season water shortages result from inefficient water distribution. People in bottom lands that are underlain by good aquifers have senior water rights. Ideally, these people could pump ground water and leave stream flow to be used by owners of high lands where adequate ground water yields cannot be acquired. However, senior water rights are exercised, and water users on the benches and terraces are left with inadequate water supplies during late summer.

2.4 Water Quality

The major problems currently associated with water quality degradation are caused by irrigation withdrawals and return flows. Irrigation withdrawal problems occur during the summer when reaches of the Bitterroot River are nearly dewatered. Minimum stream flows required to support trout fisheries are not being maintained in several portions of the Bitterroot drainage, particularly in the middle sections of the river. Unnaturally low flows lead to thermal increases and consequent decreases in dissolved oxygen. As water warms, its ability to hold oxygen in solution decreases. Irrigation return flows discharge the required water to the river, but they also return sediment

and nutrients. Increased nutrients in conjunction with elevated water temperatures can create algal blooms. As this organic matter decays, oxygen is used up by microbes that metabolize the debris, further reducing oxygen concentrations. Monitoring data from municipal and industrial sources indicate that dewatering for agricultural purposes has a more adverse effect on water quality in the Bitterroot River than the combined municipal and industrial discharges. Cite

Water quality measurements from the mouth of the river show increases in nitrate concentrations and coliform bacteria densities. Although the data show no violations of water quality standards, they do indicate some deterioration in water quality. High coliform densities, high nutrient concentrations, and increases in algae populations may result from the entrance of untreated wastes into the river. When septic systems are placed in the coarse alluvium adjacent to the river, sewage may seep laterally into the river. The increase in residential development along the river can result in this sort of contamination. Dense concentrations of livestock along the river also provide a source of bacteria and nutrients. Surface runoff from adjacent feedlots or intensively grazed areas creates pollution problems in the Bitterroot River.

III. HYDROLOGY

3.1 Annual Precipitation Trends

Total annual precipitation at Missoula is shown for 1930 through 1978 (Figure 1). These data can be used to identify relative wet and dry periods. From 1929 through 1940, the area experienced a drought with a mean annual precipitation of only 11.4 inches. For the period from 1941 to 1978, this value increased to 13.2 inches. However, the three-year period from 1944 through 1946 was also exceptionally dry with a mean annual precipitation of only 10.9 inches.

April 1 snowpack expressed as equivalent water inches is presented for the years 1937-1978 (Figure 2). These measurements were taken at Lolo Pass, Idaho, and can be used as a relative index to snowmelt contributions in different years. Snowpack was exceptionally low in 1940, 1941, 1942, 1944 and 1945. A series of years with low snowpack can result in lower peak flows in the Bitterroot River, creating temporary constancy in the river's course. Average April 1 snowpack increased from 28 inches for 1937 through 1946 to 34 inches for the period from 1947 through 1980.

3.2 Bitterroot River Stream Flow

Considering the water discharge, several aspects are important in the evaluation of river bank stability. In general, a channel achieves a pseudo-equilibrium over time so that during periods of low flow there is little erosion. With large floods, major bank erosion generally occurs. Engineers and geologists have concluded that in most river systems 90 to 99 percent of all significant bank erosion occurs during major floods. Therefore, by analyzing runoff trends, events that aggravate channel stability may be

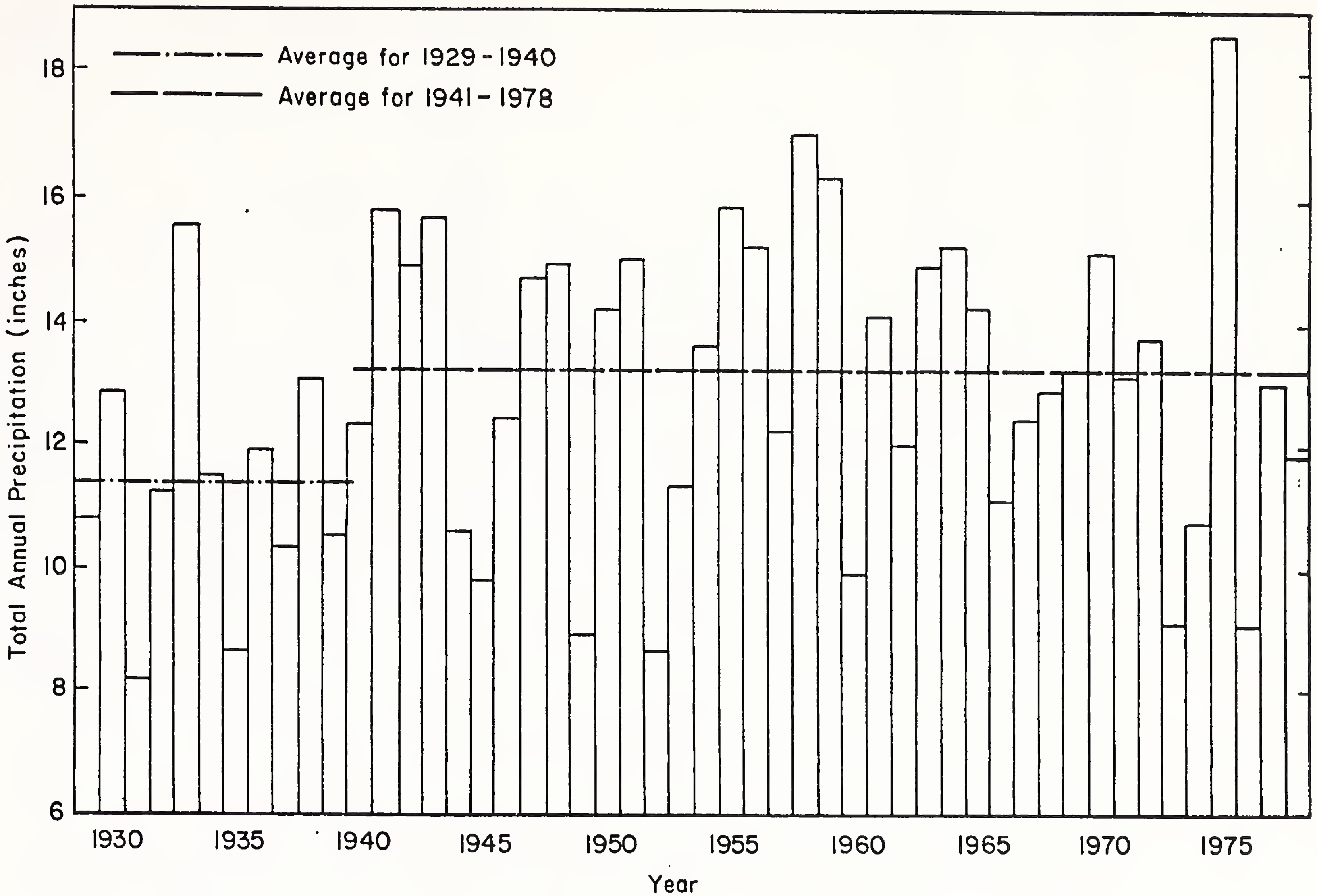

Figure 1. Annual Precipitation at Missoula, Montana: 1929:1978

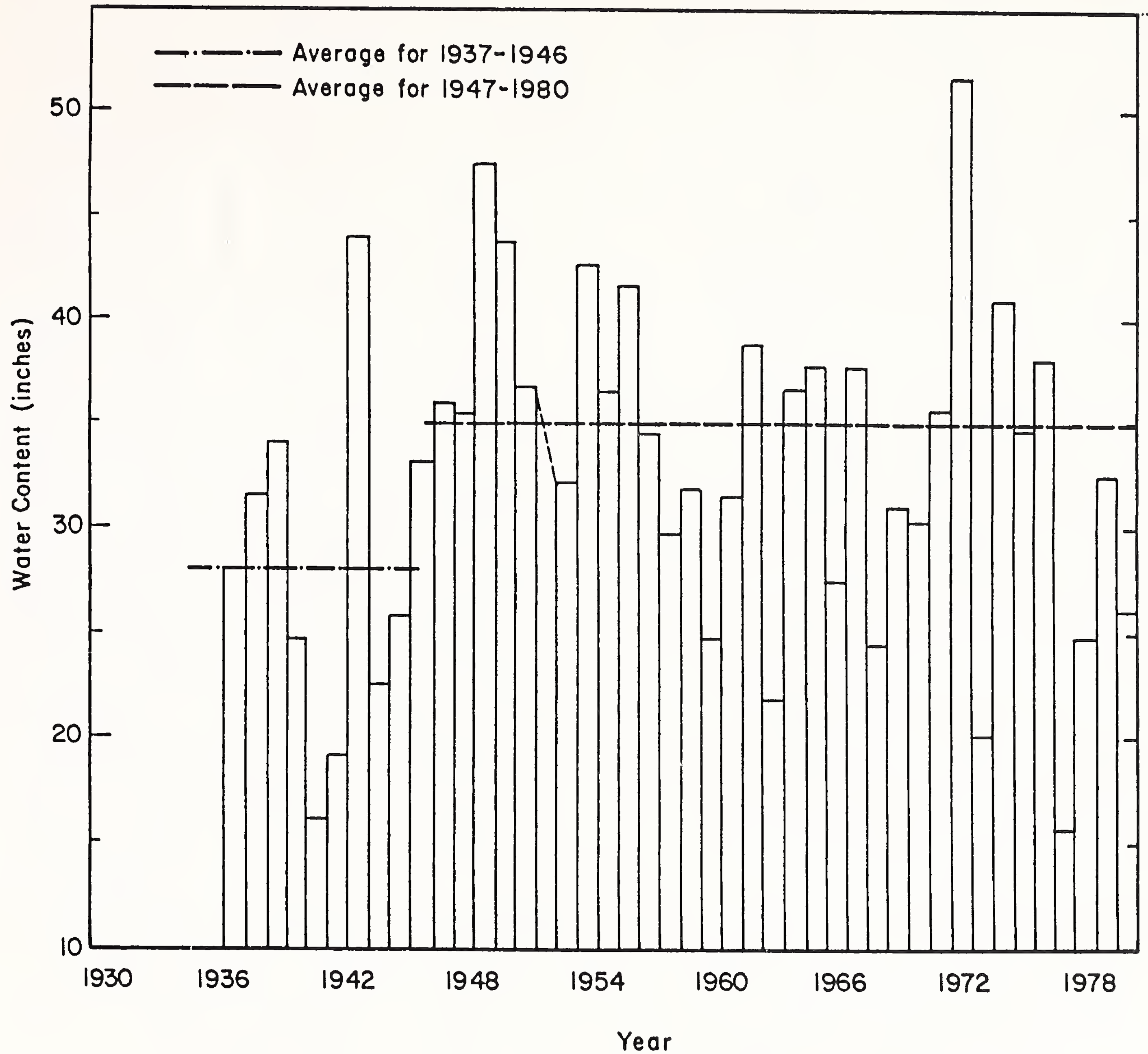

Figure 2. April 1 Snowpack at Lolo Pass, Idaho: 1937-1980

identified.

Mean monthly flows are illustrated for the Bitterroot River at Darby in Figure 3 and show that peak flows occur in May and June as a result of snowmelt. A graph of annual peak flows illustrates that from 1934 through 1946 peak spring flows were substantially lower than in subsequent years (Figure 4). The annual peak flow for 1937 through 1946 averaged only 4300 cfs, while for the years 1947 through 1978 it averaged 7100 cfs. The 1947 and 1948 peak flows of 11,500 and 11,300 cfs, respectively, correspond to major floods (approximately a 35-year recurrence interval). The occurrence of two large floods in consecutive years undoubtedly had an impact on the channel stability in the critical area between Hamilton and Stevensville. Figure also shows how mean flows for each month in 1948 differed from average mean monthly flows for the period of record. Another 35-year flood occured in 1974 at Darby.

3.3 Ground Water

The floodplain of the Bitterroot River is formed on about 40 feet of Quarternary alluvium (well-rounded cobbles, gravels, and sands). This alluvium is connected with the streams and is a good aquifer with high permeability and large storage capacity. Wells constructed in the floodplain are generally capable of supplying more than 250 gallons per minute (gpm). Ground water recharge occurs during the spring as streamflow infiltrates the aquifer. Since the ground water reservoir is usually filled to capacity by June, much of the high spring runoff is rejected. Increased pumping of ground water during the summer would lower the water table so that more streamflow could

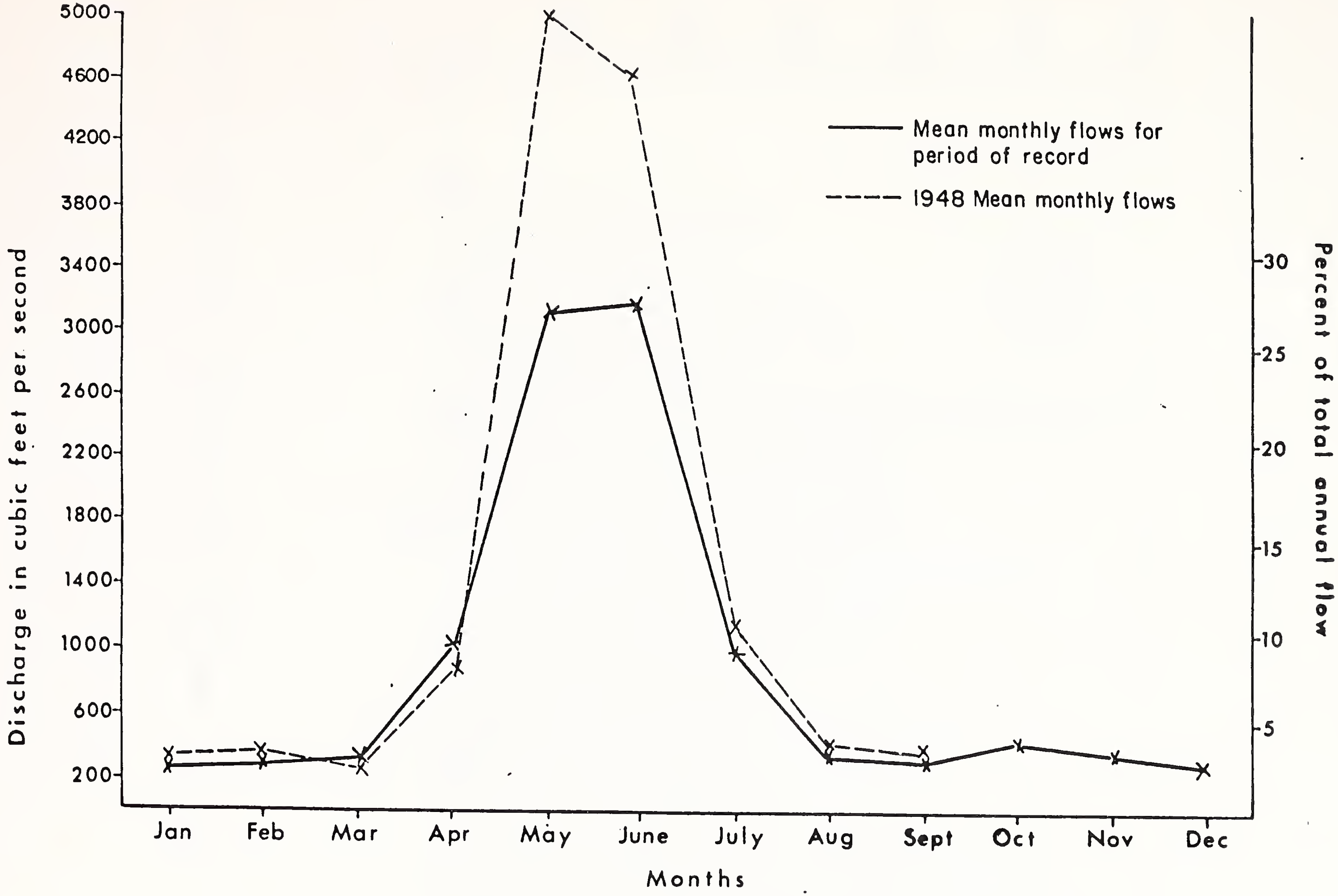

Figure 3. Mean Monthly Flows for Bitterroot River Near Darby Modified from Senger 1975.

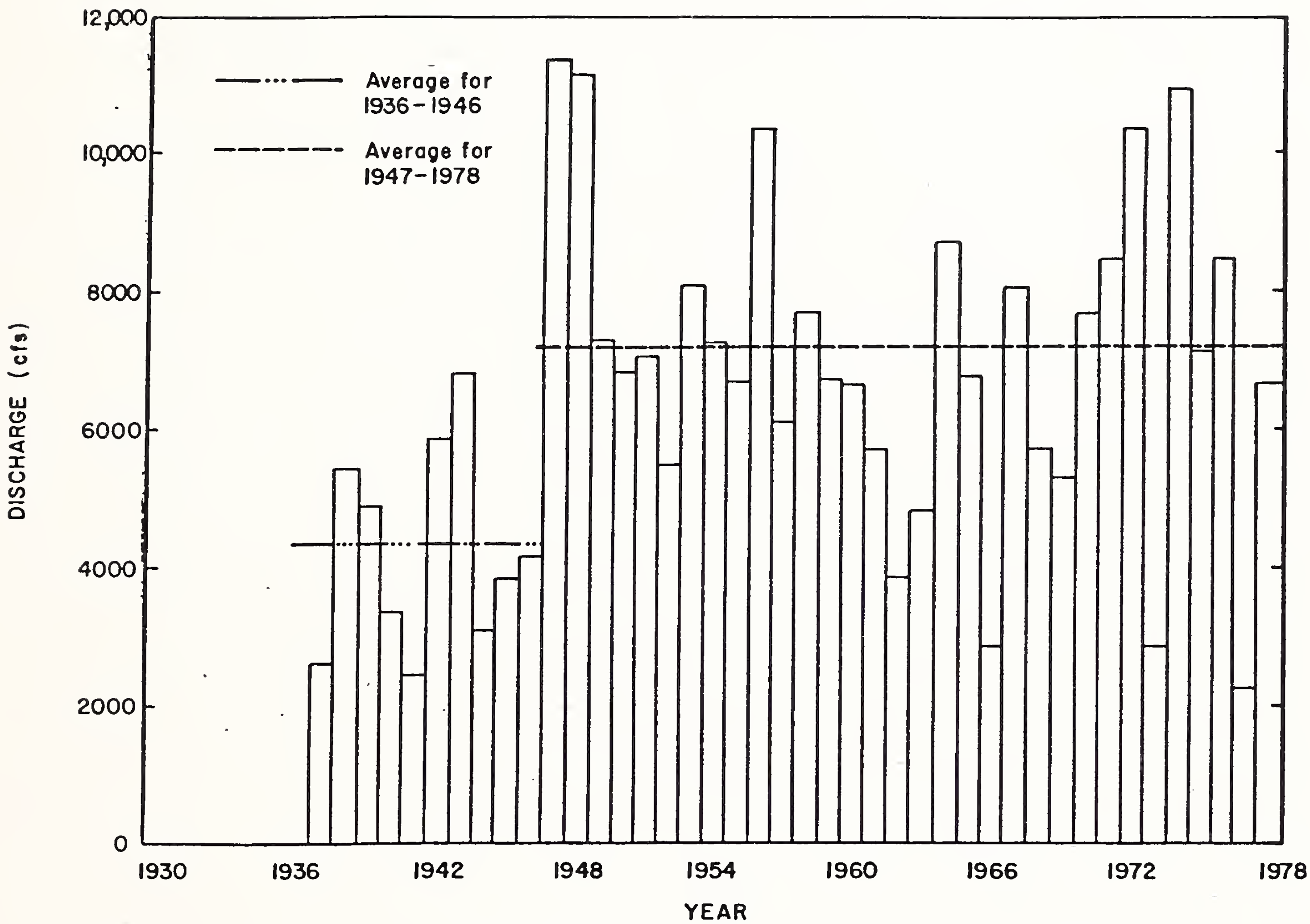

Figure 4. Peak Flows: Bitterroot River Near Darby: 1937-1978

enter the aquifer during the following spring. Thus, ground water pumping could reduce the volume of water leaving the Bitterroot Valley.

enter the aquifer during the following spring. Thus, ground water

would reduce the volume of water leaving the Blitzstrom, Valley.

IV. HYDRAULICS AND GEOMORPHOLOGY

Hydraulic characteristics of the Bitterroot River involve the movement of water and sediment through the channel. River hydraulics reflect the topography, geology, and climate of the drainage area and influence the river's morphology. The Bitterroot River flows in a relatively stable channel upstream of Hamilton. Between Hamilton and Stevensville, the river exhibits a tendency to braid, dividing into several channels that span a wide area. A braided river is characterized by multiple channels, channel bar formation, and an erosive behavior of bank attack. Additionally, a braided river is generally wide and shallow and takes a relatively straight course through a valley.

The presence of gravels and cobbles in the river bed creates an armor layer that helps to protect against erosion and degradation of the bed. However, because of the general stability of the river bed, the erosive power of the water is transmitted to the more erodible bank material. This creates localized erosion, causing random portions of the bank to erode and slough into the river. The magnitude of these processes is greatest during flood flows.

Alteration of the channel network most often occurs during peak flows in May and June. Thus, after unusually high peak flows, the channel may become repositioned in a dramatically different location. The magnitude of the peak runoff in the spring season is determined mainly by the volume of accumulated snow and the rapidity of snowmelt. Weather conditions such as continued warm spring temperatures and heavy late-spring rainfalls enhance snowmelt conditions. Rapid snowmelt sends torrents of water rushing down into the

Bitterroot River. High springtime flows are characteristic of rivers draining steep, mountainous terrain, and have a tremendous capacity to move sediments.

During extended periods of low annual peak flows, a river tends to confine itself to fewer channels and exhibits some degree of (apparent) stability. If subsequent flood years occur during relatively short time intervals, the increased erosive power of the river cuts more channels to carry the flow, and the river strays from its previously defined channel.

Based on sediment analyses and calculated sediment transport capacity, the river's ability to move sediment exceeds the sediment supply delivered to it from upstream watersheds. Thus, there is no tendency for long term net deposition in the river bed, even though there may be locally occurring deposition and aggradation over the short term of one or two years. There is also no tendency for downcutting of the bed due to its armored condition.

V. CONCLUSIONS AND POSSIBLE SOLUTIONS

5.1 Conclusions

Common characteristics of alluvial channels are the frequent changes in location, shape and hydraulics that the channel and cross sections experience with time. These changes are particularly significant during periods when alluvial channels are subjected to high flows. Approximately 90 percent of all river changes occur during that five to ten percent of the time when major floods occur (if flow duration is significant). However, any modification of natural flows can significantly alter a river system.

In the study reach between Hamilton and Stevensville, the Bitterroot River is considered a braided stream flowing through coarse glacial detritus. During peak spring flows, the river tends to shift its bed sediments and cut new channels. The magnitude and extent of erosion are dependent upon the many factors identified in this study. However, major shifts in channel alignment must be attributed to high-velocity flows during periods of flooding. Prior to 1947, the river followed a relatively consistent path through the valley. From the beginning of the period of record, 1930 to 1946, peak spring flow averages were considerably lower than those during subsequent years. For at least 16 years a combination of drought and gradual spring snowmelt created the illusion that the Bitterroot River was a stable, meandering stream. The absence of high peak spring flows allowed the river to maintain a relatively consistent course and stable channel. The significant flood events of 1947 and 1948 were the turning point. When the drought ended with two consecutive years of flooding, the river returned to its inherent braided and unstable condition. Two major flood years ocurred again in 1972 and 1974. Bank stability has also been aggravated by the composite effects of various human

activities, , including: (1) river bank alteration, (2) floodplain development, (3) logging methods and road construction, (4) irrigation diversions and practices and (5) range management and grazing practices. The Sleeping Child fire in 1961 also adversely affected channel stability.

A variety of remedial actions may be taken to enhance stability of the Bitterroot channel. They are: selection and enhancement of a stable channel alignment; storage of an adequate percentage of flood water; modification of channel cross sections; stabilization of channel bank, utilizing both structural and nonstructural measures; land-use management; irrigation diversion consolidation; and public information programs. Each measure must be considered with respect to cost and feasibility. In general, the alternatives can be categorized as structural and nonstructural measures. If none of the alternatives are implemented, the consequences of the "no-action" alternative must be considered.

5.2 Structural Measures for Channel Stabilization

Among the most direct approaches toward improving the stability of a river is the use of river training structures, both in the stream and along banks. Through the use of revetment, dikes, riprap, and levees, the stability of a river may be virtually guaranteed within the design limits. Since sediment transport in this system is normally low and the bed is already armored, downstream effects of such training are not likely to be severe. Therefore, river training could be incorporated to limit the river's freedom to move laterally. However, river training procedures are extremely expensive and the river can change alignment during the training period, negating some of the positive impacts. In order to justify the additional tax burden of such an

undertaking, a cost-benefit analysis of the project would be necessary. Since the Bitterroot River is not a navigable stream, the costs of river training are likely to outweigh the potential benefits.

Potential types of bank stabilization for the Bitterroot River include rock riprap, transverse dikes, gabion cages, grouted rock, and soil cement. Rock riprap consists of a range of sizes of rock used to construct an embankment. Transverse dikes are an indirect method of bank protection and can be either permeable or impermeable. They are used to direct the current in the desired direction and to control scour and deposition. Gabion cages are box-like rectangular baskets made of galvanized wire mesh and filled with rocks. However, gabions are not recommended where the wire mesh could be easily cut by moving boulders during high flow. Grouted rock is used when rocks of sufficient size are not available or when it is desirable to reduce the quantity of rock used for bank protection. Grouting involves filling voids with concrete. Soil-cement riprap can be used as a substitute for stone to protect the channel bank. The estimated construction costs per foot for rock riprap, gabion cages, grouted rock, and soil cement are $324, $383, $422 and $388, respectively. Such large expenses require economic justification. For example, if 3000 feet of bank protection is required, the cost for riprap (based on assumed costs) will be approximately one million dollars. A more economical approach might be through the consolidation of irrigation structures such as canals and diversions. Such consolidation could be accomplished by placing a single diversion in a relatively stable spot on the river, which can still provide water to existing private water rights. It might also allow larger expenditures for a more permanent diversion structure and bank

stabilization measures. The necessity of an economic analysis of different alternatives is apparent from these considerations.

5.3 Structural Measure - Storage

Another large-scale structural solution would be to construct flood control dams on the upper reaches of the river. The advantages of such reservoirs is that the spring runoff is trapped and released gradually throughout the rest of the year. By attenuating the peak discharges, the river would have less force to attack its banks, a meandering pattern could be established, and the stability of the entire system would be enhanced. Also, the reservoirs would provide irrigation benefits to local residents.

Again, however, this solution exhibits some drawbacks. Like all structures, dams are expensive. In addition to the cost of construction, costs relative to the purchase of senior water rights and inundated land must be considered. Finally, the creation of such an impoundment would have an enormous impact on the environment, although construction of some reservoirs would be favorable considering low-flow mitigation, channel stability, irrigation improvements, etc. Feasibility studies and environmental impact analyses would have to be conducted in order to design intelligently. While a reservoir offers advantages in flood control and water for recreation, it is not without its problems and costs.

Although not a general solution for system stability, local problems may be handled by constructing less permanent structures than those mentioned above. For some time it has been the practice to build low dams and dikes out of the larger bed material to aid in the diversion of water into canals. These structures direct river flow toward or away from some point in the

channel. Such structures are usually fairly inexpensive to construct and maintain. However, these are temporary structures likely to be destroyed or substantially damaged by high flows. Therefore, although such structures afford short-term, relatively inexpensive solutions at low flows, they should be employed with the understanding that in a river system such as the Bitterroot River they are but temporary solutions. Additionally, the use of bulldozers in the channel to construct these structures can adversely impact fisheries habitats. Low diversion dams are currently in use at a few locations on the Bitterroot River, including sites near Sleeping Child Creek, Hamilton, and Corvallis.

5.4 Nonstructural Measure - Vegetation

Vegetation of the banks has been documented as an effective method of protecting topsoil and reducing erosion. This is achieved in (at least) three ways. First, roots provide structural reinforcement and stability to the soil, thereby increasing its resistance to erosion. When exposed, roots can, in many instances, control erosion. Second and most important, leaves, branches and stems of vegetation cause a reduction of current velocity to below eroding values, and consequently deposition of sediment may follow. Third, vegetation acts as a buffer zone between the stream bank soil and any floating material such as ice, logs and debris that can cause soil failure by impact.

The use of vegetation as stream bank protection is probably the least expensive method available (although it is less effective for large channels than for small ones). Furthermore, it can blend nicely with the river environment and have a pleasing look. It is recommended for use on all small

gradient streams and also as a supplementary method to be used in conjunction with permeable type protection methods. Additionally, use of vegetation for upper bank and floodplain protection coupled with use of riprap for lower bank protection is a possible approach.

5.5 Nonstructural Method - Land-Use Management

The 100-year floodplain has been designated along the Bitterroot River. Building within the floodplain is prohibited, but this regulation is not being consistently enforced. Exceptions have been made or floodplain boundaries moved. Development on the floodplain not only encourages river instability, but can result in disastrous loss of property. Not only do floods cost the property owners, but they cost public tax dollars in federal aid to the parties directly affected by flooding. Building residences in the floodplain also endangers river water quality. Loose alluvium provides a poor medium in which to build septic systems; sewage tends to flow through the aquifer and enter the river.

The Bitterroot River channel and floodplain should be managed consistently, with an overall plan applied to the entire river. Land owners should work together and coordinate efforts to promote stabilization. Haphazard riprapping and jettying can adversely influence both downstream and upstream river stability. Before any structures are installed in the river or on its banks, thorough consideration should be given to their impact on the channel morphology.

Stream bank stabilization could be enhanced by preventing excessive abuse by cattle, sheep and man. When areas adjacent to the river are overstocked with animals, young trees and shrubs are damaged before they can establish

themselves. As mentioned, establishment of trees and shrubs in the floodplain slows peak flows and reduces the erosive power of the river. Overgrazing can also result in trampling and sloughing of stream bank material. Grazing is not necessarily detrimental to bank stability if the animals are not concentrated on those banks particularly sensitive to erosion.

The major problem with the above suggestions is that they depend on cooperation of contingent owners all along the river. Ideally, consistent floodplain management could be achieved by acquiring public ownership of lands adjacent to the river. Not only would public ownership simplify land management, but it could benefit the public in several ways. Fishing and hunting access could be provided, and more people would be allowed to enjoy the river. Lands could be leased to ranchers for grazing and forage production. But most importantly, the public could control activities in the floodplain through proper management. The Bitterroot River is inherently unstable, but management oriented towards reducing disturbances to the river system can improve conditions.

Conjunctive use of ground water and surface water may be a method of reducing peak flows to some extent. The underlying alluvium in the Bitterroot Valley is an easily rechargeable aquifer. As previously discussed, reducing the peak flows would enhance bank stability. Additionally, pumping during low flows, instead of diverting surface water, could achieve several purposes:

1. More water could remain in the channel to provide habitat and food diversity for resident trout.

2. Pumping eliminates the necessity of maintaining irrigation diversions on an unstable channel.

3. Ground water levels are lowered, creating space for peak flows the following spring. (Pumping places an expense on individual farmers, but the advantages can override the costs.)

Pumping the required volume to completely reduce peak flows to a level acceptable in terms of bank stability is practically impossible economically. However, any amount of ground water pumping, such as for irrigation uses, would contribute to reducing peak flows. Costs of irrigation pumping depend on the discharge and head required and the power costs. From a detailed example in the technical report, the annual power cost per irrigated acre for 134 acres of alfalfa was computed to be $75 for electric, $39 for natural gas and $100 for diesel.

5.6 Nonstructural Measure - Public Awareness Programs

A general public awareness of the river's responses and behavior can reduce the influence of river instability. Knowledge that improperly placed structures can create spiraling impacts upstream and downstream may impede the installation of poorly engineered developments. However, people need to understand that the Bitterroot River is inherently highly dynamic; many of the problems associated with the river are not man induced. Construction of any structure in the river or on its floodplain must be preceded by an understanding of the river's behavior. The Bitterroot River is a braided stream. Braided rivers are continually vacating and occupying, destroying and creating their channels. The most reasonable approach to dealing with such a river is to understand and respect it and to adapt human activities in the vicinity of the river. In this way, river-related damage can be minimized with the least capital output.

5.7 No-Action Alternative

The no-action alternative is the result of not pursuing any of the proposed structural or nonstructural alternatives. The conclusions of this

report indicate that the Bitterroot River, particularly in the reach between Hamilton and Stevensville, is inherently unstable and can be classified as a braided river. Under normal or typical yearly conditions, this type of river system can be expected to continue shifting within the floodplain, creating new river banks and destroying old river banks, from one year to the next. Only during a drought period, such as that experienced in the 1930's and early 1940's, can this type of river system establish some degree of stability without implementing some structural or nonstructural stabilization plan.

Should a structural alternative be considered for implementation, it is recommended that further studies be conducted to determine the river reaches where strategically located temporary or permanent structures could be placed. Careful selection is required to insure that these structures control the river in a planned and predictable manner. The success of river training techniques depends entirely on understanding how the river responds to these confining structures. Optimal sites for a limited number of diversion canals should also be located to allow consolidation of ditches. Placement of diversions in stable channel locations is critical for continuous water supply and efficient irrigation. Implementation of any alternative should simultaneously consider the use of the public awareness alternative. The benefits of this alternative towards increasing man's understanding and cooperation with nature can be far-reaching. Further research is required to provide a more thorough understanding of the Bitterroot River's behavior and to enhance its beneficial attributes.

VI. BIBLIOGRAPHY

6.1 Literature

Bitterroot Conservation District, 1980. Long Range Program for Soil and Water Conservation. Hamilton, Montana.

Cartier, K.D., and K. R. Curry, 1980. Erosion and Stream Channel Stability in the Bitterroot River Watershed of Southwestern Montana. Department of Geology, University of Montana, Missoula, Montana.

Chow, V. T., 1959. Open Channel Hydraulics. McGraw-Hill, New York, New York.

Colby, B. R., 1964. Practial Computations of Bed-Material Discharge. Journal of the Hydraulics Division, ASCE 90 (HY2).

Farnes, P. E., and B. A. Shafer, 1972. Hydrology of the Bitterroot River Drainage. USDA Soil Conservation Service, Bozeman, Montana.

Farnes, P. E., and B. A. Shafer, 1974 and 1975. Water Supply Outlook for Montana, USDA Soil Conservation Service, Bozeman, Montana.

Federal Emergency Management Agency (FEMA), 1980. Flood Insurance Study of Ravalli County, Montana.

Ganser, T. J., D. J. Peters and D. L. Tennant. 1979. Bitterroot River Natural Resource and Physical Features Inventory. USDA Soil Conservation Service, Bozeman, Montana.

Garn, H. S., and R. C. Malmgren, 1973. Soil and Water Resources of the Bitterroot National Forest, Montana, Part I. USDA Forest Service, Bitterroot National Forest, Hamilton, Montana.

Gessler, J., 1971. "Beginning and Ceasing of Sediment Motion," Chapter 7 in River Mechanics, edited by H. W. Shen, Fort Collins, Colorado.

Lane, E. W., 1947. Report of the Subcommittee on Sediment Terminology. Transactions of the American Geophysical Union 28(6):936-938.

Lane, E. W., 1957. A Study of the Shape of Channels Formed by Natural Streams Flowing in Erodible Material. M.R.D. Sediment Series 9. U.S. Army Engineers division, Missouri River. Corps of Engineers, Omaha, Nebraska.

McMurtrey, R. G., R. L. Konizeski, M. V. Johnson and J. H. Bartells, 1972. Geology and Water Resources of the Bitterroot Valley, Southwestern Montana. U.S. Geological Survey Water Supply Paper 1889.

Meyer-Peter, E., and R. Muller, 1948. Formulas for Bed Load Transport. Proceedings, Third Meeting of International Association for Hydraulic Research, Stockholm, pp. 39-64.

Montana Department of Natural Resources and Conservation, 1976. Flow Records for Gaging Stations on the Bitterroot River 1968-1976. Helena, Montana.

Montana Department of Natural Resources and Conservation. Water Quality Inventory and Management Plan: Lower Clark Fork River Basin.

Montana State Engineer, 1958. Water Resources Survey: Ravalli County, Montana. Montana State Engineers Office, Helena, Montana.

Montana Water Resources Board, 1969. Summary of Potential Projects in Montana. Inventory Series No. 9, Helena, Montana.

Montana Water Resources Board, 1971. River Basin Modeling - An Approach to Computer Simulation of the Bitterroot-Clark Fork River Basin, Helena, Montana.

National Oceanic and Atmospheric Administration (NOAA), Hourly Precipitation Data, National Climatic Center, Asheville, North Carolina.

Nolan, K. M., 1973. Floodplain Mapping and Planning Report for the 50- and 100-Year Flood Zones of the Bitterroot Valley, Montana. Department of Geology, University of Montana, Missoula, Montana.

Schumm, S. A., 1977. The Fluvial System. Wiley-Interscience, New York, NY.

Senger, J. A., 1975. A Compilation and Synthesis of Existing Water Resource Information on the Bitterroot Drainage, Montana. M.S. Thesis, University of Montana, Missoula, Montana.

Simons, D. B., and F. Senturk, 1977. Sediment Transport Technology. Water Resources Publications, Fort Collins, Colorado.

Simons, D. B., et al., 1980. Training Manual - Watershed and Stream Mechanics. Research Institute of Colorado, Fort Collins, Colorado.

USDA Soil Conservation Service, 1959. Soil Survey, Bitterroot Valley Area, Montana. Montana State Agricultural Experiment Station, Bozeman, Montana.

USDA Soil Conservation Service, 1970. Summary of Snow Survey Measurements for Montana 1922-69. Bozeman, Montana.

U.S. Environmental Protection Agency, Water Division, 1975. Bitterroot Drainage, Montana Field Review.

USDI Geological Survey, 1927-69. Water Supply Papers. Surface Water Supply of the United States, Part 12. Pacific Slope Basins in Washington and Upper Columbia River Basin.

USDI Geological Survey. 1970-78. Water Resources Data for Montana.

USDI Geological Survey, 1967. Topographic Maps.

6.2 Aerial Photographs

USDA Agricultural Stabilization and Conservation Service. Photographs taken in 1972.

USDA Soil Conservation Service. Photographs taken in 1937 and 1976.

USDI Geological Survey. Photographs taken in 1979.

APPENDIX

APPENDIX

Glossary

Aggradation	Deposition of sediments resulting in long-term vertical rising of the river bed.
Alluvium	Materials deposited by flowing water.
Aquifer	A water-bearing layer of permeable rock, sand or gravel.
Braided river	A generally wide river with poorly defined and unstable banks, characterized by a steep, shallow course with multiple channel divisions around alluvial islands.
Bulk sediment	A mass of sediment consisting of both solid particles and intersticial void spaces.
cfs	Cubic feet per second, referring to water discharge.
Degradation	Erosion of sediments resulting in long-term vertical downcutting of the river bed.
Discharge hydrograph	A graphical illustration of stream discharge changing with time.
Fluvial	Produced by stream action.
Geomorphic	Related to processes forming the relief of the earth's surface.
Hydraulics	Properties and processes related to flowing water.
Meandering river	A river that consists of alternating bends, giving an S-shape appearance to the plan view of the channel.
Recurrence interval (return period)	The expected time interval between the recurrence of a flow of a specific magnitude.